

Exercise walk-through

1.1

Physical quantities

A-Level Physics

1.1 Physical quantities

Name: _____ Class: _____ Date: _____

Total: 11 marks

KEY WORDS physical quantities • magnitude • unit
• order of magnitude • derived quantity

Objective

Build the skills to answer exam questions on **physical quantities** – magnitude and unit, and making sensible estimates.

You must be able to:

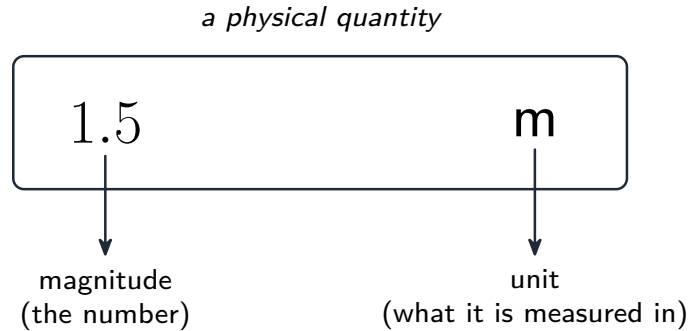
- state that every physical quantity has a **magnitude** and a **unit**
- make reasonable **estimates** of common quantities
- give an answer to the right **order of magnitude** (power of ten)

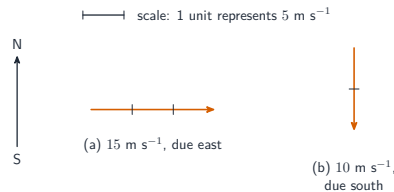
1 Worked examples

Study these first. Each one shows the method for a question type used later – follow the steps and you can do the Practice and Exam-style questions yourself.

■ Magnitude and unit

A physical quantity needs **both** a number and a unit. “The length is 1.5” means nothing; “the length is 1.5 m” is complete:





Quantities are scalars or vectors

■ Making estimates

Learn these rough values so you can check whether an answer is sensible:

quantity	estimate
mass of an adult	$\sim 70 \text{ kg}$
height of an adult	$\sim 1.7 \text{ m}$
mass of an apple	$\sim 0.1 \text{ kg}$ (weight $\approx 1 \text{ N}$)
speed of sound in air	$\sim 340 \frac{\text{m}}{\text{s}}$
speed of light (vacuum)	$3.0 \times 10^8 \frac{\text{m}}{\text{s}}$
free-fall acceleration	$g \approx 9.81 \text{ m s}^{-2}$

■ Order of magnitude

The **order of magnitude** is the nearest power of ten. A good estimate has the right power of ten: an adult's mass is $\sim 10^2 \text{ kg}$ (70 kg), **not** 10^1 kg (7 kg). To estimate the seconds in a day, keep the units so they cancel:

$$24 \text{ h} \times \frac{60 \text{ min}}{1 \text{ h}} \times \frac{60 \text{ s}}{1 \text{ min}} = 86\,400 \text{ s} \approx 9 \times 10^4 \text{ s},$$

so the order of magnitude is 10^5 s .

■ Estimating a derived quantity

Combine sensible estimates. The **pressure** a standing person exerts on the floor: weight $\approx 700 \text{ N}$, area of two feet $\approx 0.02 \text{ m}^2$. Substitute with the units still attached:

$$p = \frac{F}{A} \approx \frac{700 \text{ N}}{0.02 \text{ m}^2} = 3.5 \times 10^4 \text{ N m}^{-2} = 3.5 \times 10^4 \text{ Pa}.$$

■ Recognising quantities and estimates

Distinguish the quantity from its unit: temperature is measured in kelvin, time in seconds or minutes, potential difference in volts, and spring constant in N/m. A quantity has a measurable numerical magnitude; a unit name or a category alone does not state a quantity. Values may be fractional and units may be non-SI. Visible light has wavelengths roughly 400–700 nm; green is about 540 nm ($1 \text{ nm} = 10^{-9} \text{ m}$).

Exercises 2.1·2.2

2.1 A student writes “the mass is 60”. State what is **missing** to make it a physical quantity. [1]

60

2.2 Estimate the **mass of an apple**, giving a unit. [1]



Exercises 2.1·2.2

2.1 A student writes “the mass is 60”. State what is **missing** to make it a physical quantity. [1]



2.1

- “the mass is 60” gives a magnitude only
- a physical quantity also needs a **unit** – e.g. 60 kg

2.2 Estimate the **mass of an apple**, giving a unit. [1]



2.2

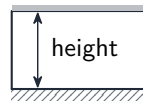
- an apple is about 100 g (from the estimate table)
- $1 \text{ g} = 10^{-3} \text{ kg}$, so $100 \text{ g} = 100 \times 10^{-3} \text{ kg} = \mathbf{0.1 \text{ kg}}$
- any value $\sim 0.05\text{--}0.2 \text{ kg}$ with a unit is accepted

Exercises 2.3-2.4

2.3 State the **order of magnitude** of the speed of light in a vacuum, in $\frac{\text{m}}{\text{s}}$. [1]



2.4 Estimate the **height** of a typical room (floor to ceiling), giving a unit. [1]



Exercises 2.3·2.4

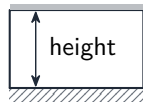
2.3 State the **order of magnitude** of the speed of light in a vacuum, in $\frac{\text{m}}{\text{s}}$. [1]



2.3

- speed of light = $3.0 \times 10^8 \frac{\text{m}}{\text{s}}$
- write as $a \times 10^n$ with $1 \leq a < 10$: here $3.0 \times 10^8 \frac{\text{m}}{\text{s}}$
- coefficient 3.0 is nearer 1 than 10, so the order of magnitude is $10^8 \frac{\text{m}}{\text{s}}$

2.4 Estimate the **height of a typical room** (floor to ceiling), giving a unit. [1]



2.4

- an adult is about 1.7 m tall, so a room is a little taller: **2.5 m**
- any value $\sim 2\text{--}3$ m with a unit is accepted

Exercise 3.1

3.1 What must all physical quantities have?

[1]

☐

A a direction and a magnitude

B a direction and a unit

C a magnitude and a prefix

D a magnitude and a unit



Exercise 3.1

3.1 What must all physical quantities have?

[1]

☐

A a direction and a magnitude

B a direction and a unit

C a magnitude and a prefix

D a magnitude and a unit



3.1 D

- every physical quantity has a **magnitude** and a **unit**
- "1.5" is not a length; "1.5 m" is
- **A** and **B** add a direction – that describes a *vector*, not every quantity
- **C** a prefix (k, m, μ) is not a unit

Exercise 3.2

3.2 Which is the best estimate of the **mass of an adult human**?

[1]

☐

A 7 kg

B 70 kg

C 700 kg

D 7000 kg



Exercise 3.2

3.2 Which is the best estimate of the **mass of an adult human**?

[1]

☐

A 7 kg

B 70 kg

C 700 kg

D 7000 kg



3.2 B

- the estimate table gives an adult's mass ~ 70 kg
- **A** 7 kg is a cat; **C** 700 kg a horse; **D** 7000 kg a truck

Exercise 3.3

3.3 Estimate the number of **seconds in one day**. Give your answer to an **order of magnitude**. [2]



1 day

Exercise 3.3

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1 day

3.3

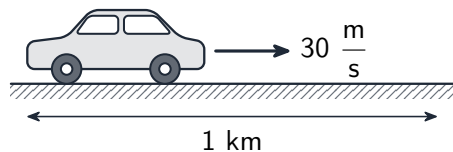
- 1 day = 24 h; keep the units so they cancel

$$24 \text{ h} \times \frac{60 \text{ min}}{1 \text{ h}} \times \frac{60 \text{ s}}{1 \text{ min}} = 86\,400 \text{ s}$$

- $86\,400 \text{ s} = 8.64 \times 10^4 \text{ s} \approx 9 \times 10^4 \text{ s}$ (1 s.f.)
- leading digit $9 \geq 5$, so round up: order of magnitude **10^5 s**

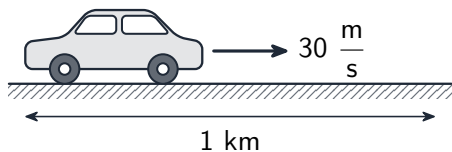
Exercise 3.4

3.4 A car travels at about $30 \frac{\text{m}}{\text{s}}$. Estimate the time it takes to travel 1 km, and state the **order of magnitude** of that time in seconds. [2]



Exercise 3.4

3.4 A car travels at about $30 \frac{\text{m}}{\text{s}}$. Estimate the time it takes to travel 1 km, and state the **order of magnitude** of that time in seconds. [2]



3.4

- $s = 1 \text{ km} = 1000 \text{ m}, v = 30 \frac{\text{m}}{\text{s}}$

$$t = \frac{s}{v} = \frac{1000 \text{ m}}{30 \frac{\text{m}}{\text{s}}} \approx 33 \text{ s}$$

- $33 \text{ s} = 3.3 \times 10^1 \text{ s} \approx 3 \times 10^1 \text{ s}$ (1 s.f.)
- leading digit $3 < 5$, so order of magnitude **10^1** s

Exercise 3.5

3.5 A person of weight 700 N stands on both feet, total contact area about 0.02 m^2 . Which is the best estimate of the pressure on the floor? [1]

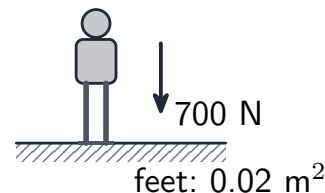
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A $1.4 \times 10^4 \text{ Pa}$

B $3.5 \times 10^4 \text{ Pa}$

C $3.5 \times 10^6 \text{ Pa}$

D $1.4 \times 10^7 \text{ Pa}$



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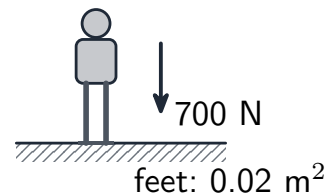
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C $3.5 \times 10^6 \text{ Pa}$

D $1.4 \times 10^7 \text{ Pa}$



3.5 B

$$p = \frac{F}{A} = \frac{700 \text{ N}}{0.02 \text{ m}^2} = 3.5 \times 10^4 \text{ N m}^{-2} = \mathbf{3.5 \times 10^4 \text{ Pa}}$$

- **A** is too small (wrong A , or $F \times A$)
- **C** and **D** are far too large (area probably left in cm^2)